

# ***Training Image Characterization and Multipoint Statistical Modeling of Clastic and Carbonate Formations***

**2014 Rocky Mountain Section AAPG Annual Meeting  
Denver, Colorado  
July 20–22, 2014**

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**Energy & Environmental Research Center (EERC)**

# Presentation Outline

- Background
  - Plains CO<sub>2</sub> Reduction (PCOR) Partnership
- Characterization methods
  - Modeling workflow
  - Multiple-point statistics
  - Training image creation
    - ♦ Carbonate
    - ♦ Clastic
  - Application
- Conclusions

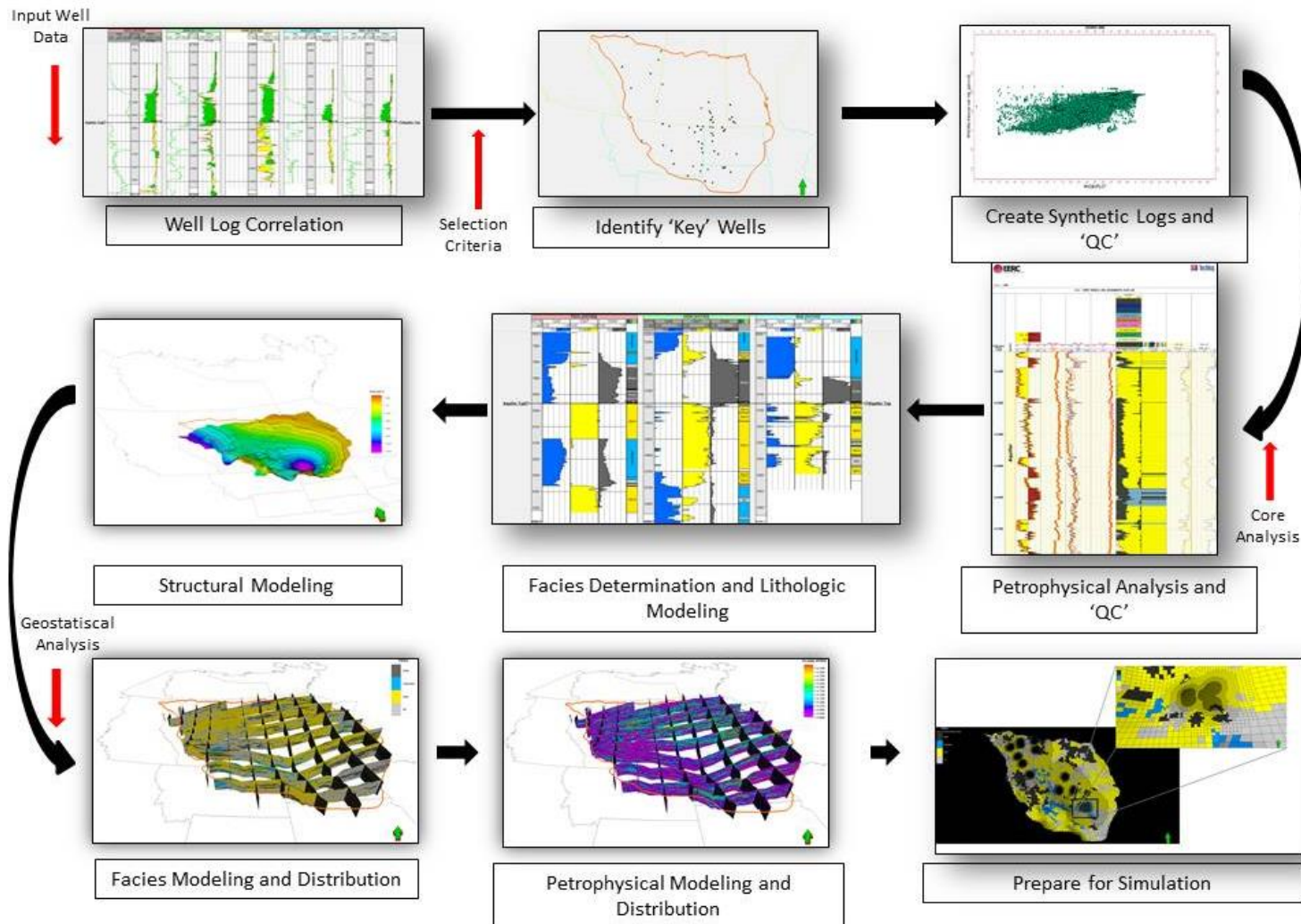




# PCOR Partnership



# Geocellular Modeling Workflow



# Workflow Solutions

- Lack of data concerning reservoir characterization:
  - **Multiple-point statistics (MPS) facies distribution**
    - ◆ Apply geologic interpretations
    - ◆ Apply modern analogs for spatial relationships
    - ◆ Needs a **Training Image**



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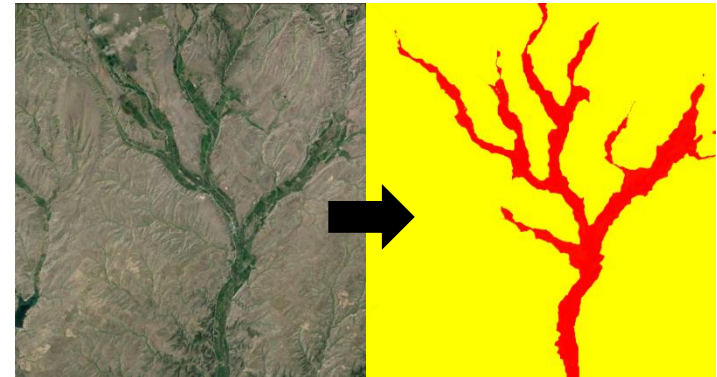
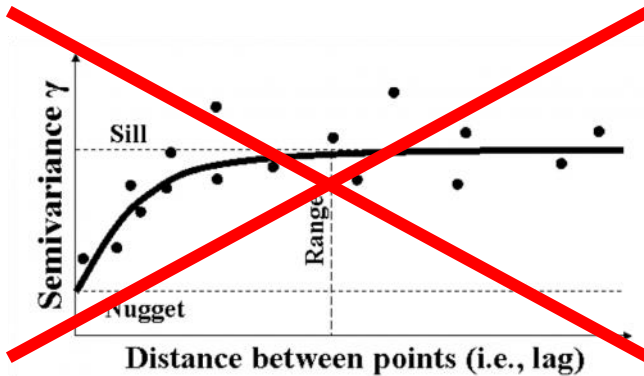
# What Is A Training Image???

# According to Google....





# What Is a Training Image?

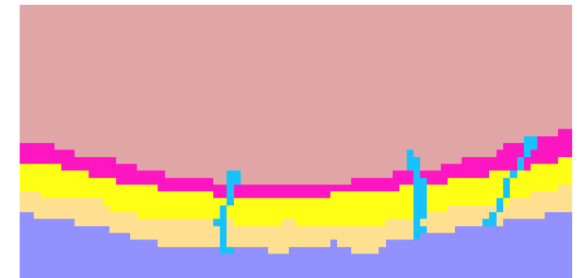
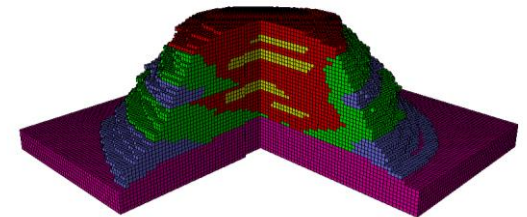
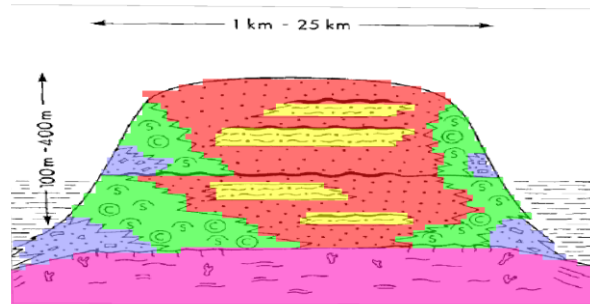
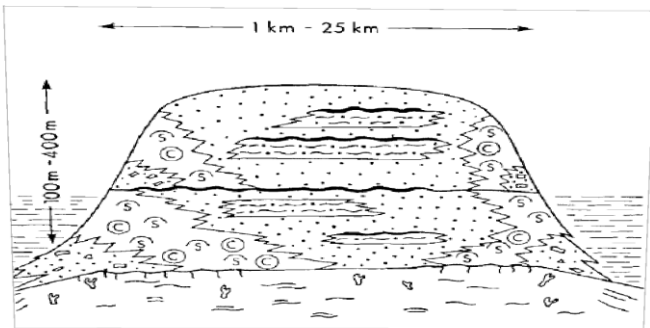


- Answers the question: In a given geologic scenario, how does the data vary in space?
- Template or database containing geostatistical information which computers may consume to calculate spatial probabilities
  - Geologic constituents
  - Geologic patterns (depositional, erosional, diagenetic, etc.)
  - Proportions of pattern constituents
  - Requires knowledge and confidence in your geologic understanding
    - ♦ Fluvial deposits: channel width, depth, sinuosity, drainage pattern, orientation, migration, etc.
  - What else is required for MPS?
    - ♦ Initial conditions (control points) to help guide the MPS facies distribution



# Training Images

- Clarification: training “image” implies 2-D; most reservoir facies models are created from a 3-D training image (training image grid).
- Derivation: illustration, photograph, object created by the user, other...
- Caution: keep it simple!
  - Software-based MPS distributions can be computationally intensive; complexity can be counterproductive.
    - ◆ Number of variables (facies), training image resolution (number of cells)



# MPS Facies Distribution (basic 2-D example)

Area to Receive  
Distribution:

	1(A)	
	0(?)	3(B)
	2(B)	

Training Image:

A	A	A
B	A	B
A	B	A

Search Radius:

	1	
4	U	2
	3	

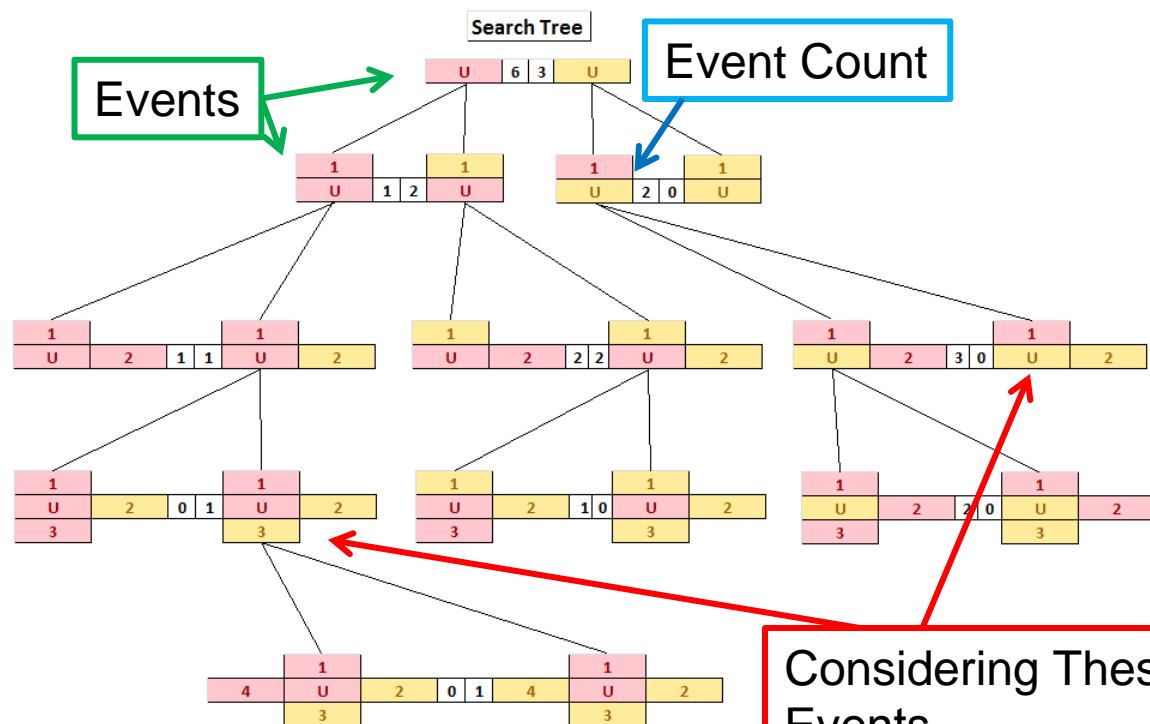
Possible outcomes: point zero  
may have Value "A" (Fig. 1) or  
Value "B" (Fig. 2):

1

	1(A)	
	0(A)	3(B)
	2(B)	

2

	1(A)	
	0(B)	3(B)
	2(B)	



Conditional probabilities are  
calculated for the events in  
the search tree; the most  
probable event is honored.

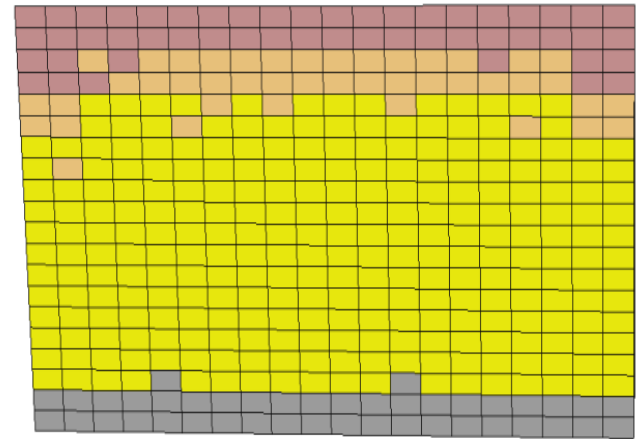
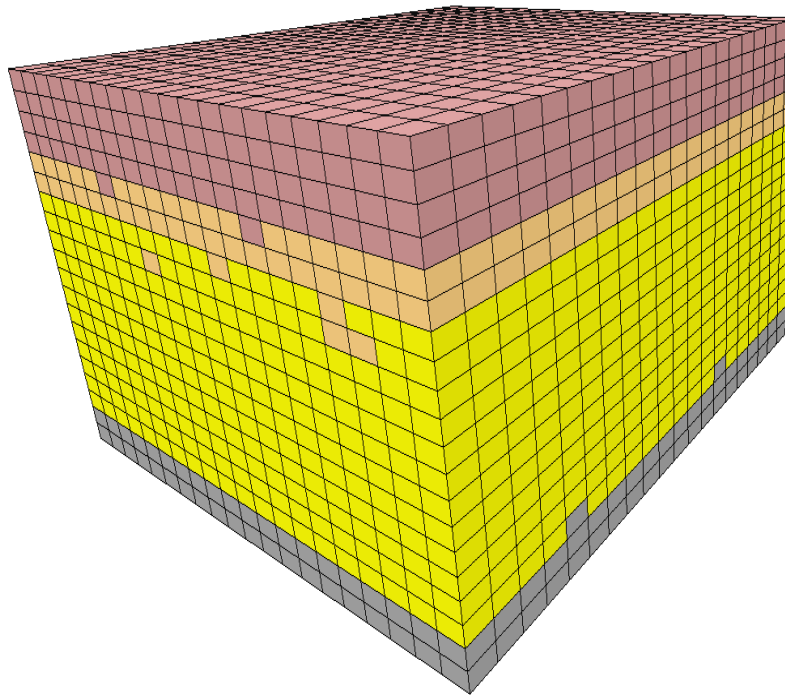
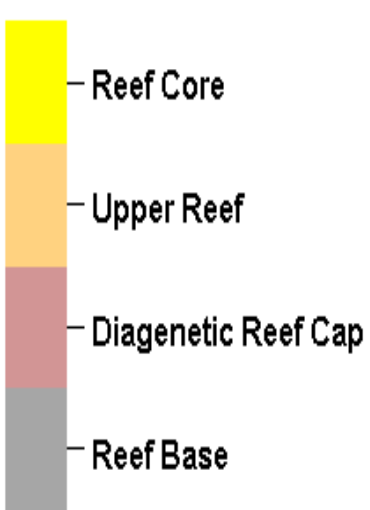
- The training image contains one event which agrees with Value "A," while no events agree with Value "B."
- Scenario depicted in Fig. 1 is most probable.



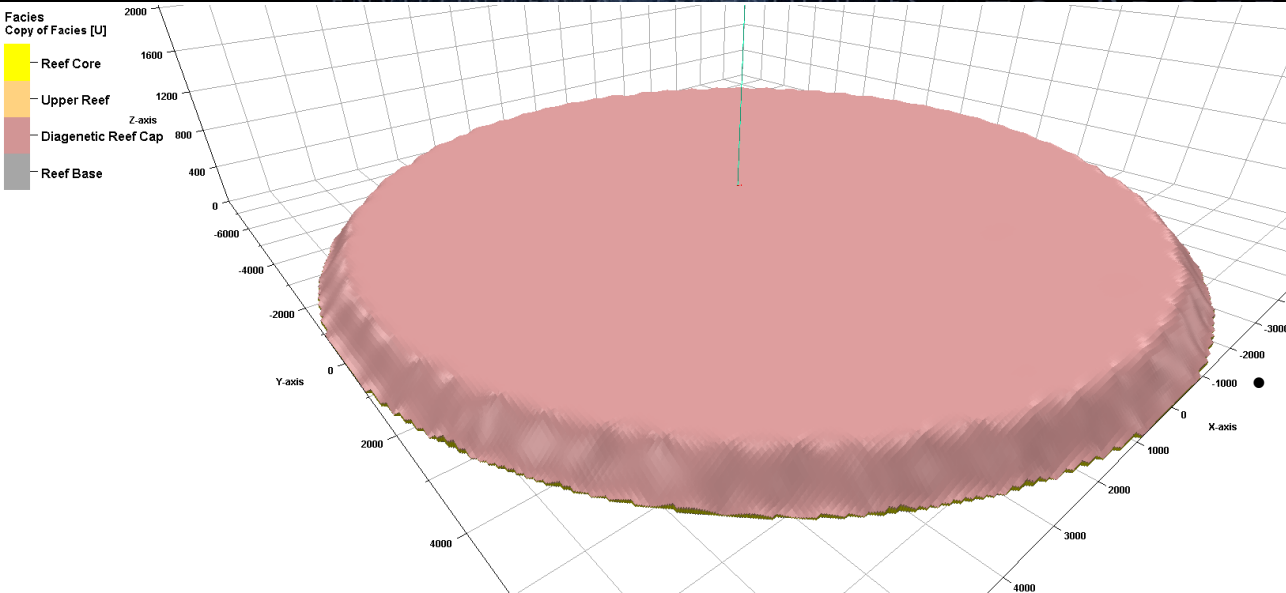
# Training Image → Model (carbonate systems)

Pinnacle Reef Training Image

Facies  
Facies [U]

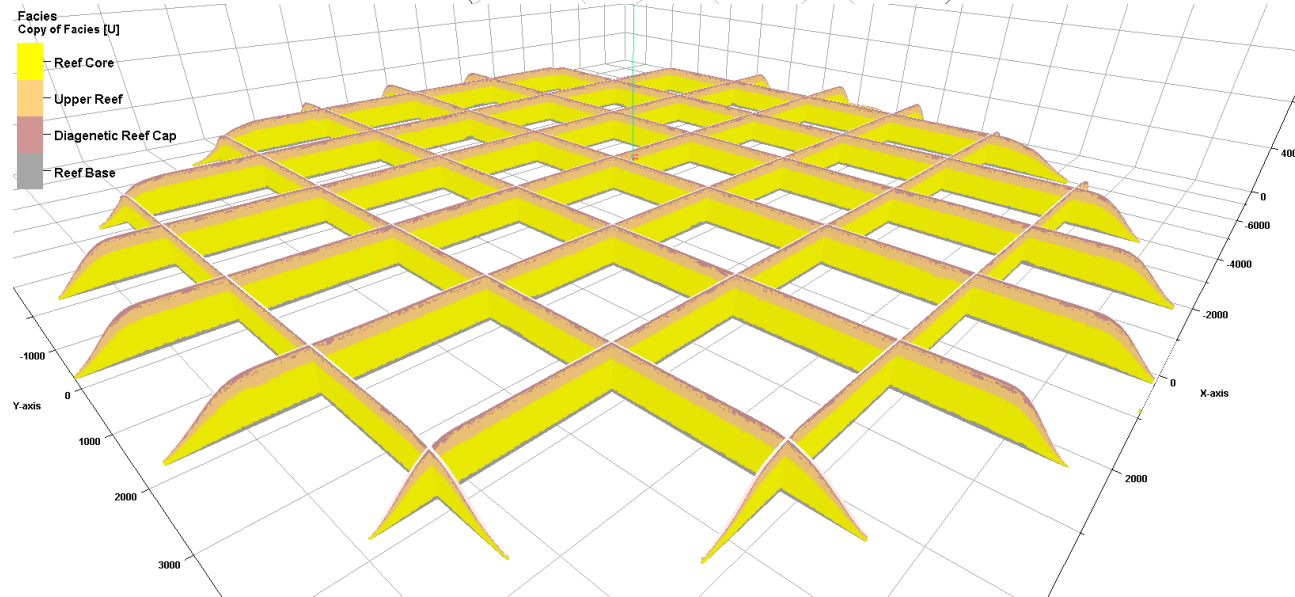
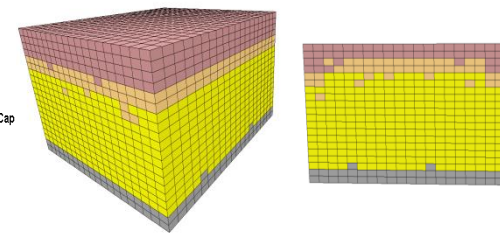


# Training Image → Model (carbonate systems)



## • Pinnacle reef model:

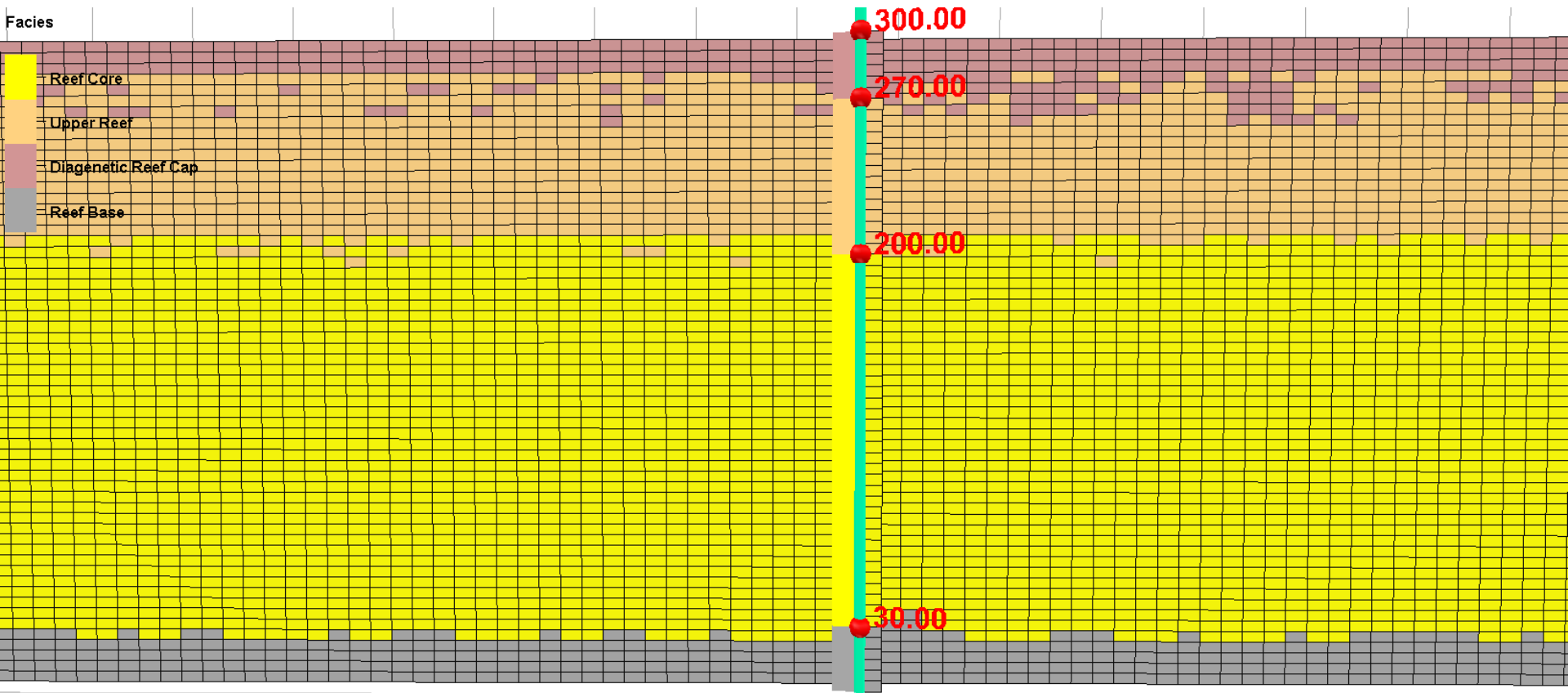
- 3-mile base diameter; 300 ft in relief
- Cell size: 20 ft × 20 ft × 5 ft
- 38 million cells





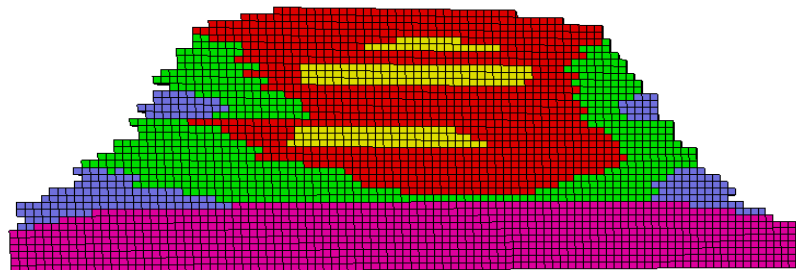
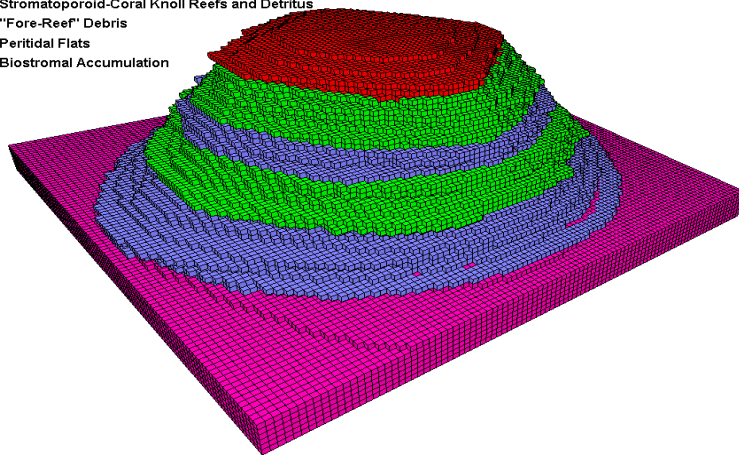
# Training Image → Model (carbonate systems)

- The MPS facies distribution replicates facies associations found in the training image while honoring control points.
- Why use MPS?
  - Capture internal heterogeneity for more realistic models



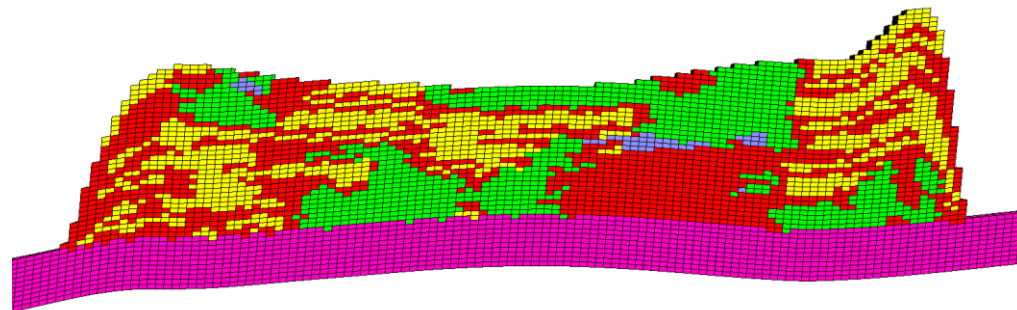
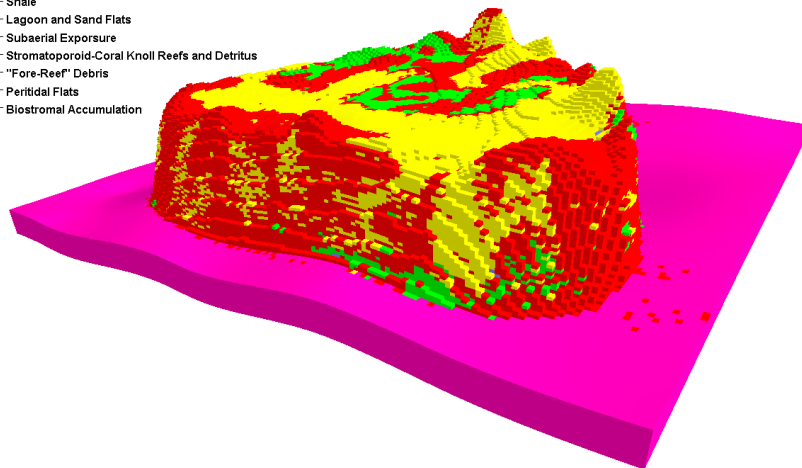
# Training Image → Model (carbonate systems)

- Basin
- Lagoon and Sand Flats
- Subaerial Exposure
- Stromatoporeid-Coral Knoll Reefs and Detritus
- "Fore-Reef" Debris
- Peritidal Flats
- Biostromal Accumulation



Copy of Facies  
Copy of Facies\_FINAL

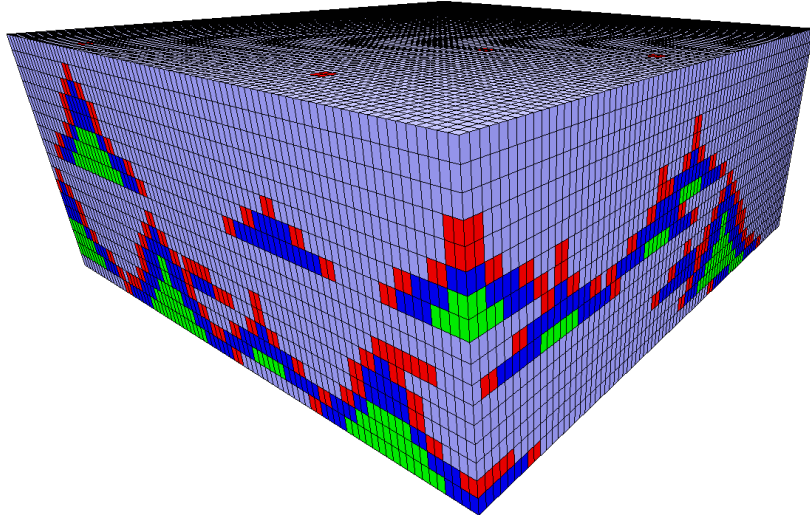
- Shale
- Lagoon and Sand Flats
- Subaerial Exposure
- Stromatoporeid-Coral Knoll Reefs and Detritus
- "Fore-Reef" Debris
- Peritidal Flats
- Biostromal Accumulation





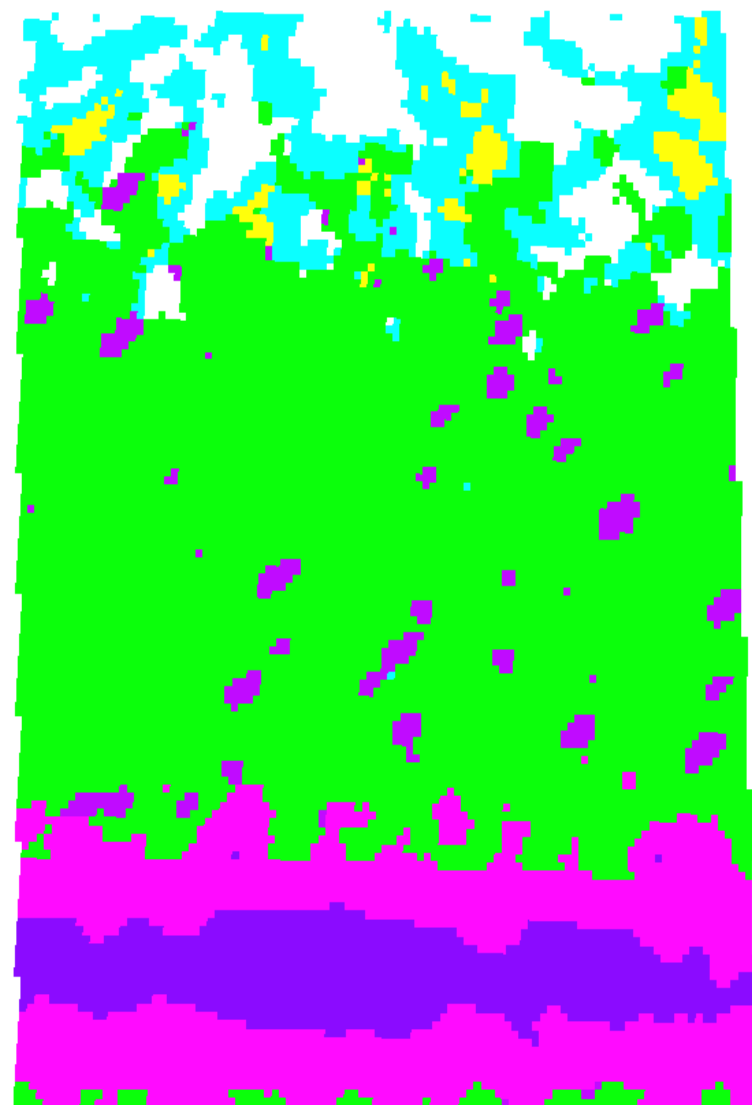
# Training Image $\rightarrow$ Model (carbonate systems)

## Carbonate Mounds

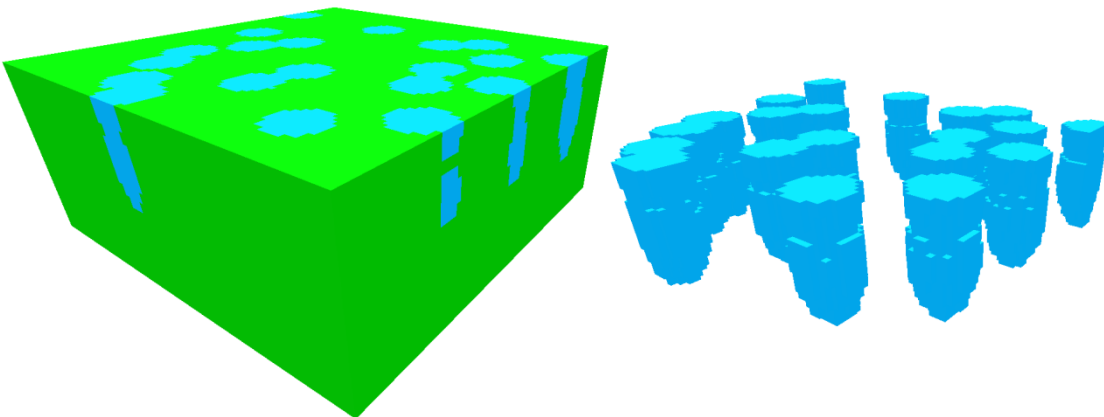


- Carbonate Shelf  
Carbonate Fine [U]
- Platform margin reef
  - Back and fore reef
  - Restricted shelf lagoon
  - Mud
  - Patch reefs
  - Carbonate sand
  - Reef talus
  - Shelf limestone

## Carbonate Shallow Shelf



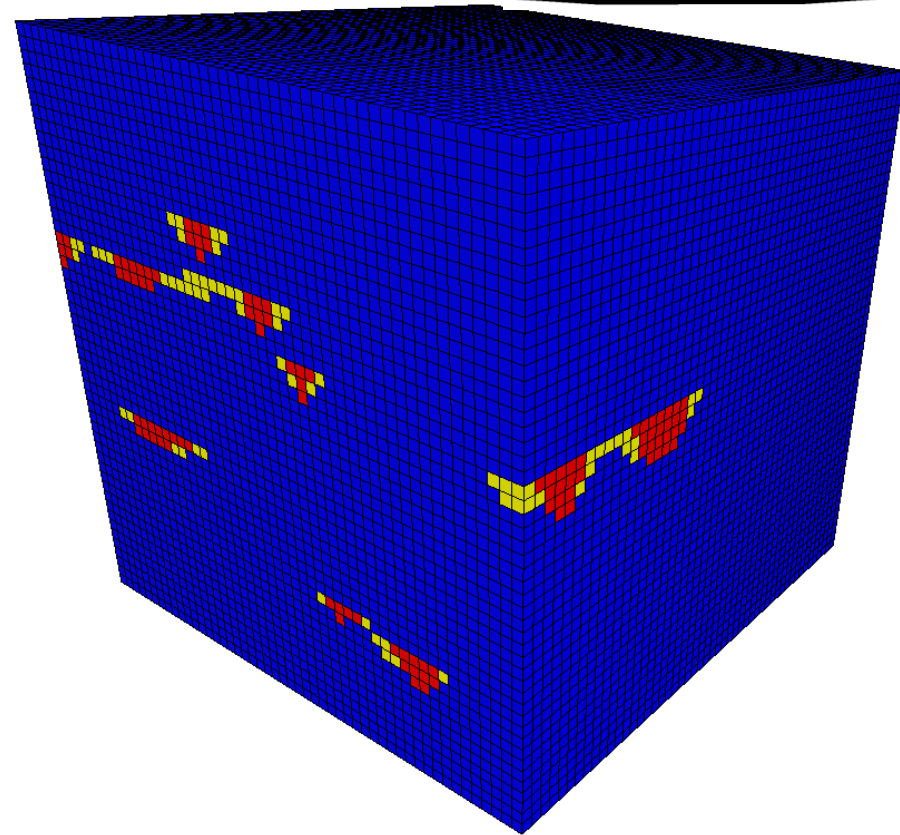
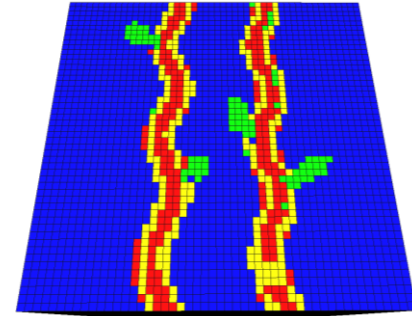
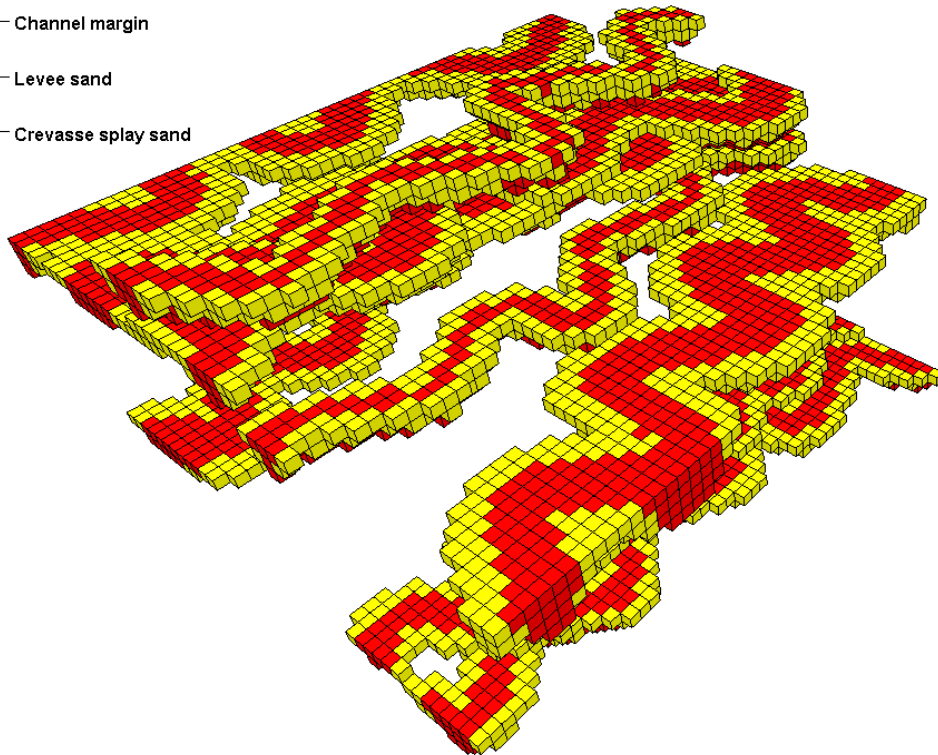
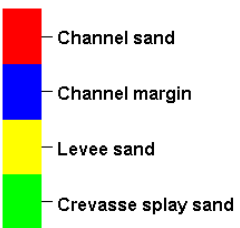
## Karst



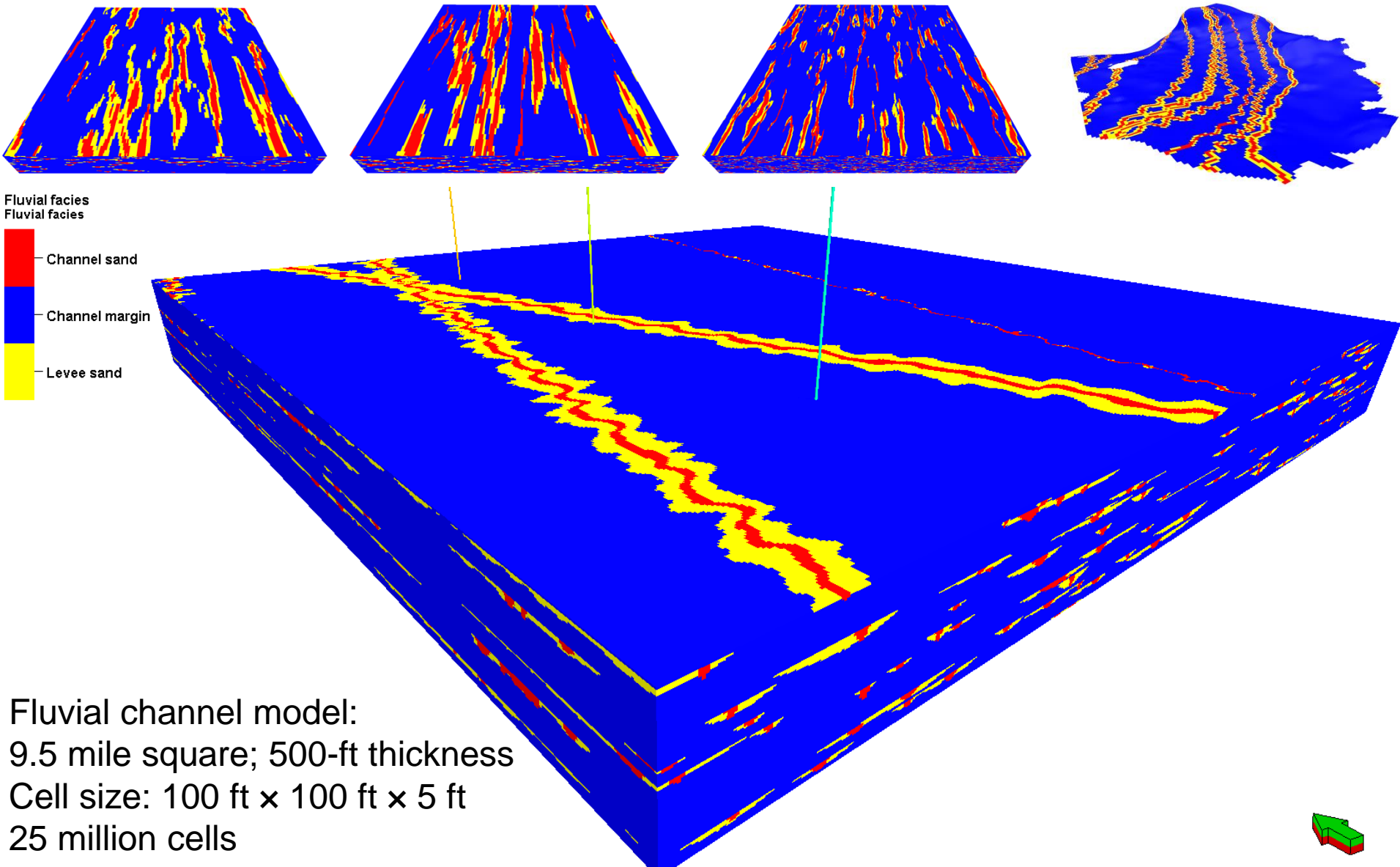
# Training Image → Model (clastic systems)

- Object modeling: fluvial channel training image creation
  - Variables: width, depth, sinuosity, etc.

Fluvial facies  
Fluvial facies



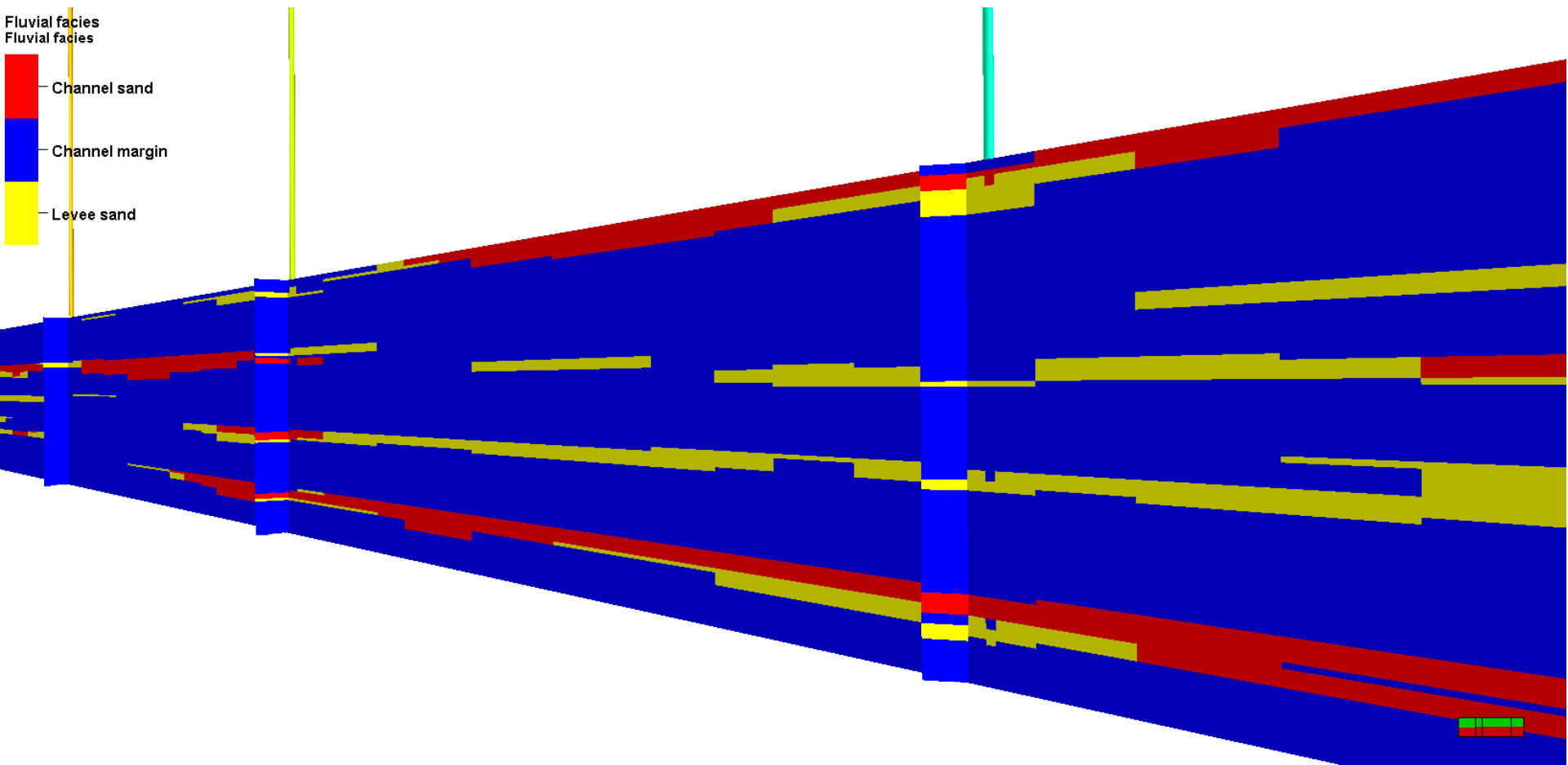
# Training Image → Model (clastic systems)





# Training Image → Model (clastic systems)

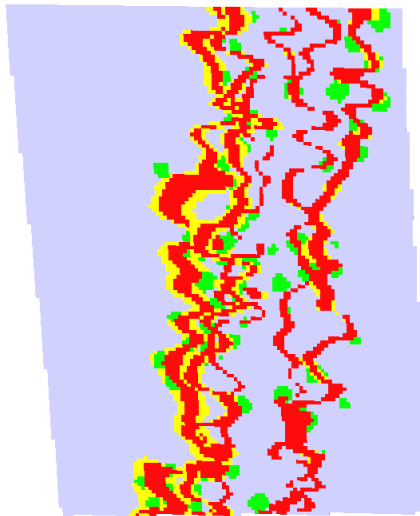
- Control points
  - Facies logs used as “hard data” for the MPS distribution



# Training Image → Model (clastic systems)

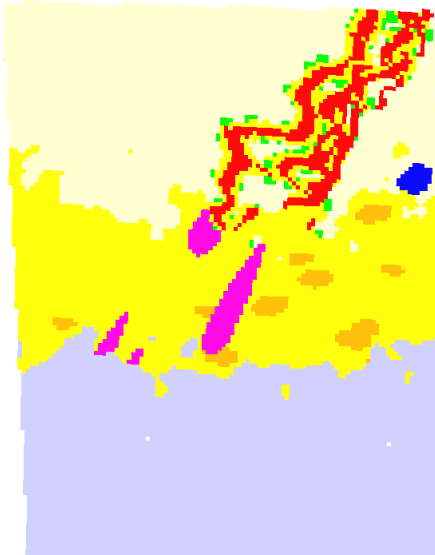
Facies  
Adaptive channel with Splays [U]

- Shale
- Channel
- Levee
- Lobe
- Splay



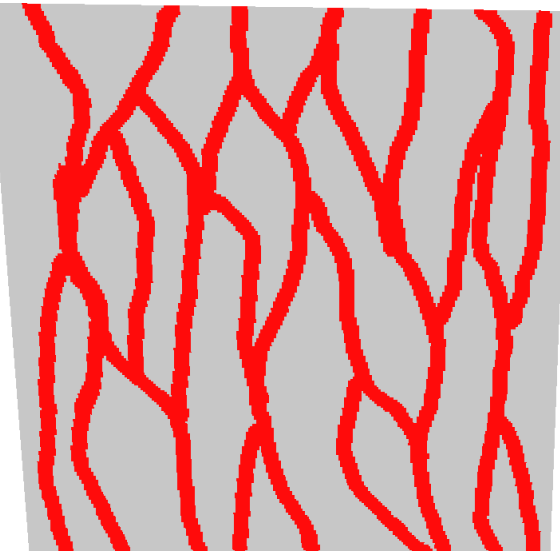
Delta  
Delta Fine 1 run [U]

- Inner
- Slope
- Basin
- Channel
- Levee
- Splay
- Fan lobes
- Floodplain
- Lacustrine
- Sand bars
- Slope Muds
- Shoreface



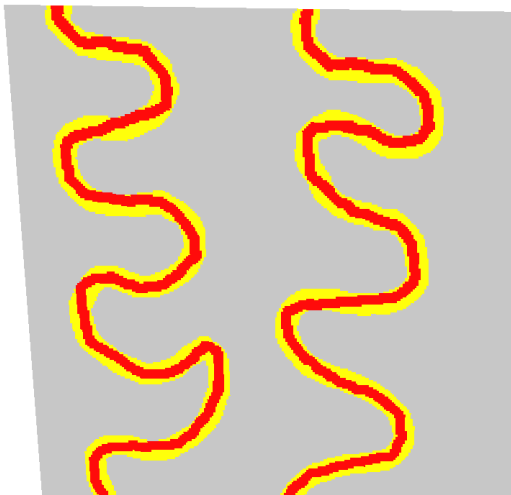
Facies  
2D Anastomosing Channels

- Shale
- Channel
- Levee
- Crevasse
- Lobe
- Platform
- Mouthbar
- Pointbar
- Karst



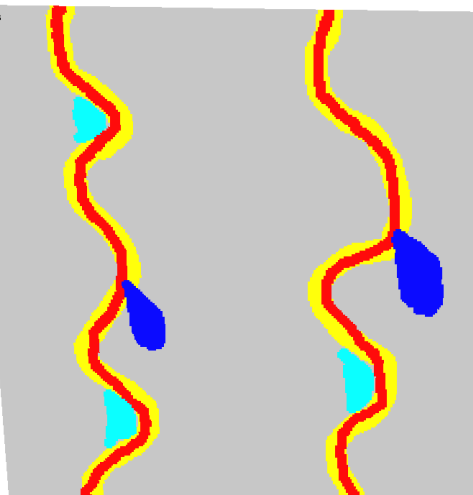
Facies  
2D Meandering Channels

- Shale
- Channel
- Levee
- Crevasse
- Lobe
- Platform
- Mouthbar
- Pointbar
- Karst



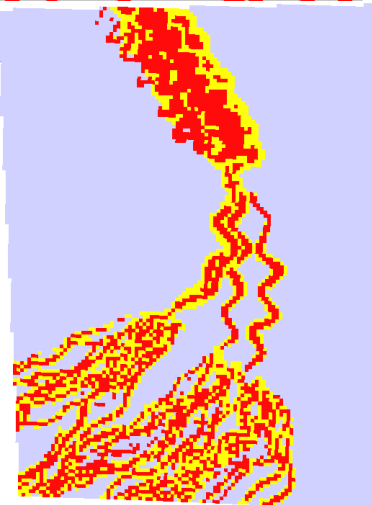
Facies  
2D Channels\_Crevasse\_PointsBars

- Shale
- Channel
- Levee
- Crevasse
- Lobe
- Platform
- Mouthbar
- Pointbar
- Karst



Facies  
Complex fluvial channel [U]

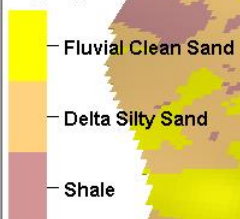
- Shale
- Channel
- Levee
- Lobe
- Splay



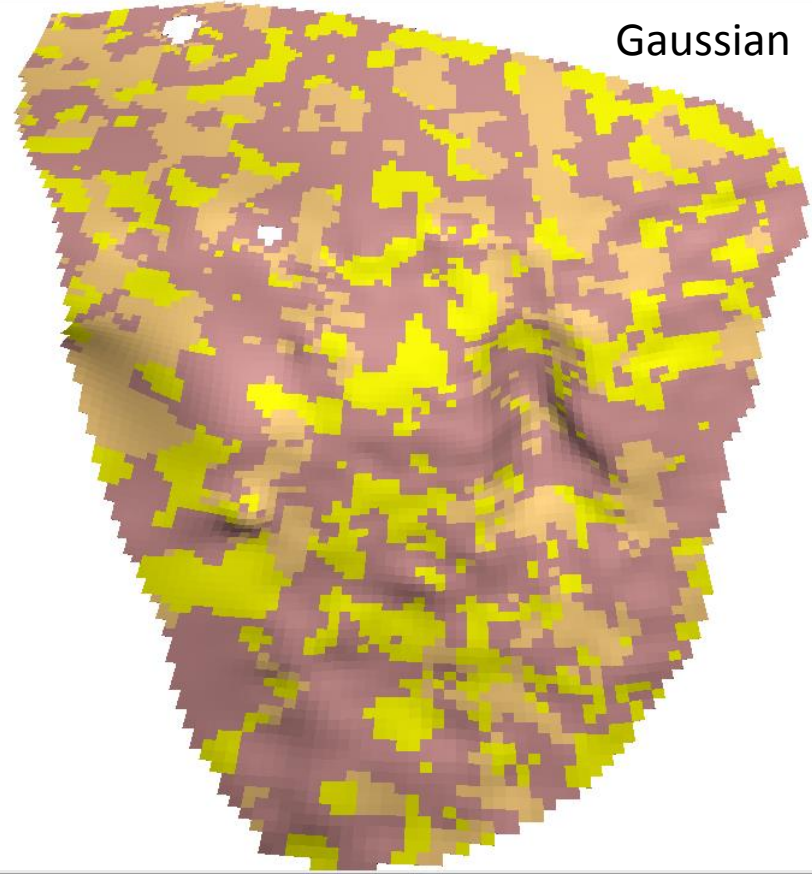
# MPS vs. Conventional Geostatistics: Fluvial-Deltaic Facies



Facies  
Clipped\_MPS\_Facies



MPS



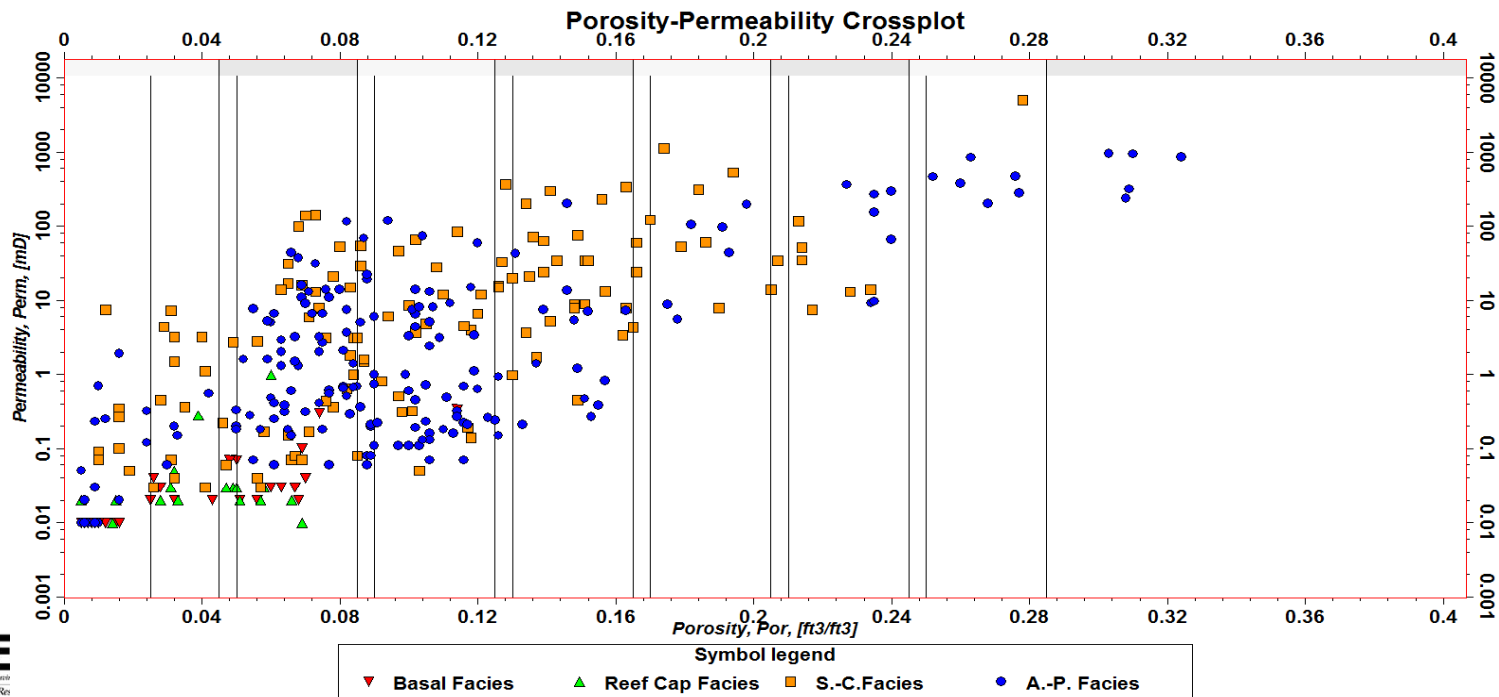
Gaussian



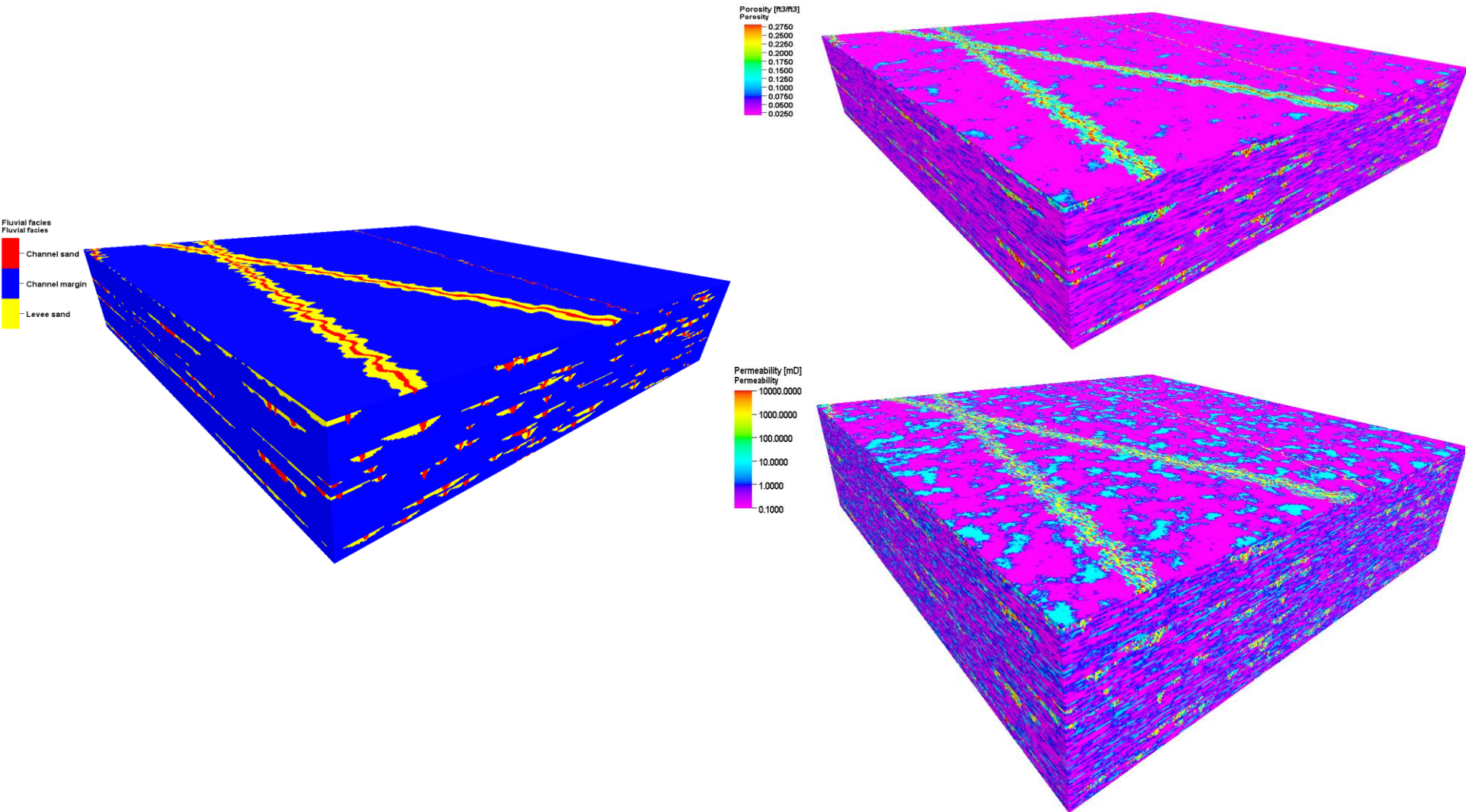


# Petrophysical Modeling

- Complex facies modeling allows us increased accuracy in distributing petrophysical properties (porosity and permeability).
  - Petrophysical property distributions may be conditioned to the facies model.
  - Bivariate statistics (or cloud transform) can be used to populate permeability with conditioning to both facies and porosity.



# Petrophysical Modeling



# Conclusions

- MPS is not new (just new to geomodeling software).
- MPS is becoming an important tool in geologic characterization resource assessment.
  - Geobody and facies modeling in unsampled locations
- MPS excels in capturing internal heterogeneity for more realistic models.



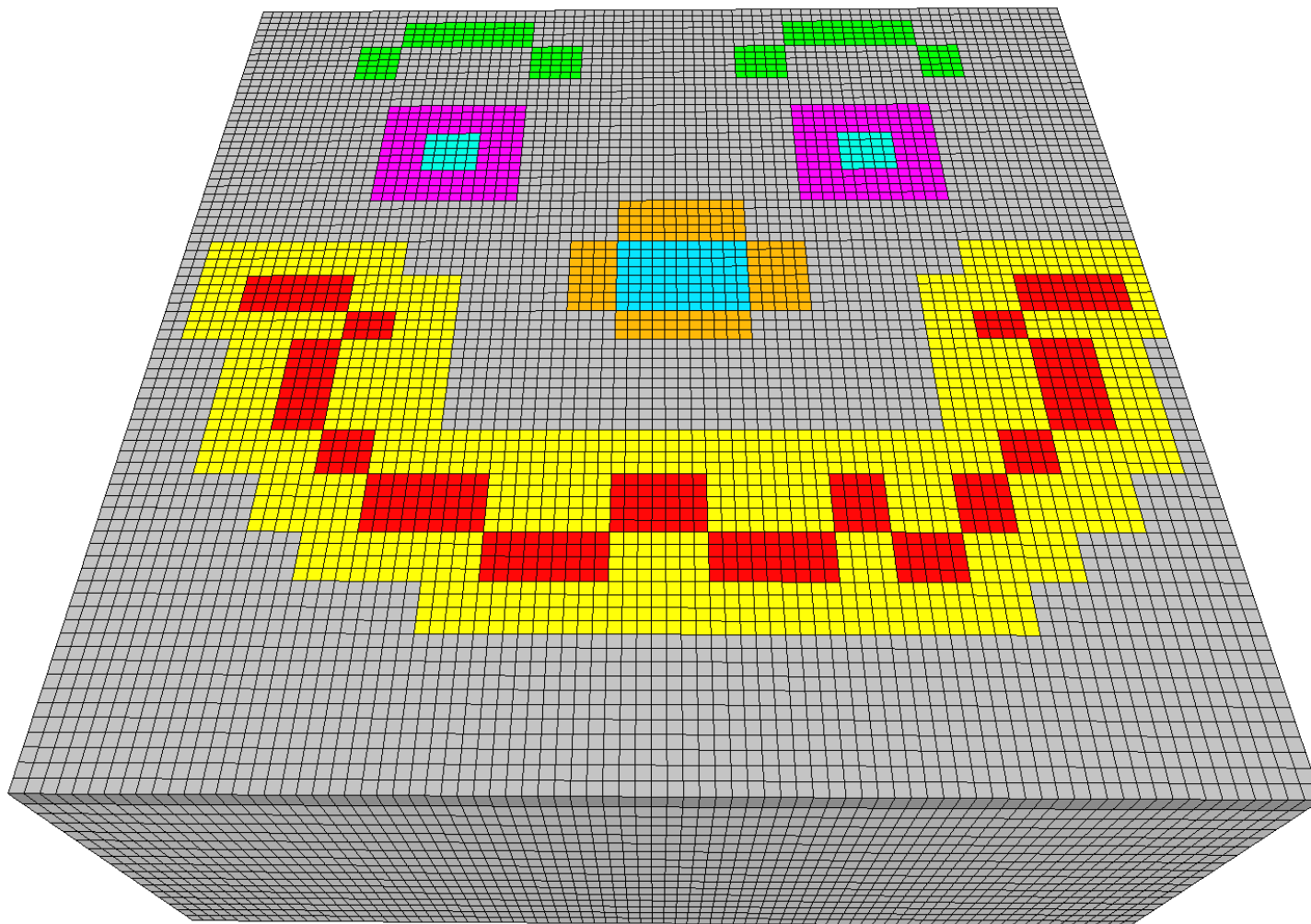
# Conclusions

- Important considerations for MPS:
  - Incorporates a developed knowledge of reservoir facies associations in space.
  - Using MPS without understanding reservoir spatial characteristics is dangerous!
    - ◆ MPS will reproduce the training image associations within the model (whether it is accurate or not).
    - ◆ The training image must be representative of the target reservoir (facies proportions, channel size, anisotropy, etc.).
    - ◆ Even with a valid training image, the results will not be accurate without control points.
      - Initial well data (facies logs) are needed to guide the MPS facies distribution.

# Thank You!

Facies

- Shale
- Channel
- Levee
- Crevasse
- Lobe
- Platform
- Mouthbar
- Pointbar
- Karst



# Contact Information

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## Acknowledgment

This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory under Award Nos. DE-FE0009114 and DE-FC26-05NT42592.

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